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**PROGRAM MANAGEMENT PLAN:  
RELIABILITY AND MAINTAINABILITY IMPROVEMENT PROGRAM  
FOR THE U.S. MERCHANT FLEET**

April 1977

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Prepared for  
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FOR THE U.S. MERCHANT FLEET

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Thomas/McCarthy  
Steven D./Packard

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ARINC Research Corporation  
a Subsidiary of Aeronautical Radio, Inc.  
2551 Riva Road  
Annapolis, Maryland 21401

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National Maritime Research Center  
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## FOREWORD

In April 1976, the Maritime Administration initiated the first phase of a four-phase program to improve the reliability and maintainability of equipment used in the U.S. merchant fleet. The first phase is concluded with the publication of this document, which constitutes the Management Plan for the conduct of the remaining phases of the program.

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## CHAPTER ONE

### INTRODUCTION

#### 1.1 BACKGROUND

Recent cost trends in the U.S. merchant fleet indicate that maintenance and repair costs of vessels and shipboard equipment are rising rapidly and now represent a larger burden on fleet revenue than ever before. According to data maintained by the Maritime Administration (MarAd), maintenance and repair costs for the U.S. merchant fleet, operating under subsidy, exceed \$65,000,000 per year. The increase in maintenance and repair costs is of concern to the Maritime Administration as well as to the management of shipping companies. These increased costs, particularly with respect to the electronic systems used aboard U.S. merchant ships, suggest reliability levels that fall short of acceptable standards for marine systems.

In April 1976, the Maritime Administration, in response to increasing equipment reliability problems in the U.S. merchant fleet, started development of a four-phase program to improve the reliability and maintainability of shipboard equipment. A principal goal of the program is to assist the industry in establishing certification requirements and equipment acquisition procedures that will result in improved equipment Reliability and Maintainability (R&M) characteristics.

During Phase I of the Program (April 1976 through April 1977), the Maritime Administration acquired information on the use of R&M technology in the U.S. merchant fleet. This information showed that the reliability of ship systems has been largely a function of the requirements promulgated by ship owners. Reliability requirements have been made known to the suppliers of marine equipment through natural market forces in a slow, painstaking, trial-and-error process. The merchant shipping industry has progressed to the point, however, where the complexity of equipment and systems aboard modern merchant ships makes the application of formal reliability and maintainability engineering methods essential for profitable operation. The pressure to reduce labor costs has led to greater ship automation in the engine room,

on the bridge, and in the cargo-handling areas, which in turn has created a more urgent need for reliable systems. Shipping company management is now faced with complex questions involving financial trade-offs in acquiring ships and systems based on equipment purchase cost and operation/support costs.

The reliability of ships and systems not only affects the operation of the ship itself but can have an enormous impact on the consequential risks of ship operation. The liability for a single oil spill or marine mishap can exceed the entire assets of a company. In today's environment, therefore, management must consider reliability not only in terms of potential for increasing profit but also in terms of probability of avoiding loss.

The trend toward larger, more automated vessels is likely to continue, with an ever-increasing demand for improved equipment reliability. The R&M Improvement Program sponsored by MarAd will provide a valuable service to the maritime industry, through the formal application of reliability engineering practices to the U.S. merchant fleet. The program will provide the means for measuring the actual reliability and maintainability of equipment aboard U.S. merchant ships. It will also enable the industry to address the subject of reliability improvement on an industry-wide basis, rather than in piecemeal fashion as has been predominantly the case in the past. In addition, increased attention by the industry to equipment R&M should elicit similar attention on the part of the marine equipment supply industry.

The attention to detail that is characteristic of an R&M improvement effort will help the industry to determine and document the causes of unreliability of shipboard equipment, develop recommendations for improvement, and disseminate findings throughout the merchant marine community. The lessons learned will make it possible for the industry, with the assistance of MarAd, to develop procedures for preparing equipment specifications that address R&M adequately, ensuring improved reliability and maintainability characteristics of future generations of equipment introduced into the U.S. merchant fleet.

## 1.2 PROGRAM OBJECTIVES

The major objectives of the MarAd-sponsored R&M Improvement Program are to improve the reliability and maintainability of equipment now in use in the U.S. merchant fleet and to



assist the U.S. merchant shipping industry in establishing certification and acquisition procedures that adequately address R&M requirements in future equipment acquisitions. These objectives will be achieved by the accomplishment of a logical sequence of tasks:

- Determine the present status of R&M technology in use in the U.S. maritime industry, identify alternative R&M concepts, and develop a program management plan to introduce the necessary R&M technology
- Examine the alternative R&M concepts, select a preferred concept, and develop a Pilot Program Plan to introduce the preferred R&M concept into the U.S. merchant fleet
- Conduct a Pilot Program to validate the expected benefits of the preferred R&M concept and, after review of the Pilot Program results, prepare a plan for fleet-wide implementation of the R&M Improvement Program
- Implement the R&M Improvement Program in the U.S. merchant fleet on a continuing basis

The manner in which the tasks described above will be executed is the subject of this Program Management Plan.

### 1.3 PLAN CONTENT

This R&M Program Management Plan consists of four chapters and two appendixes. Chapter One has provided an introduction to the need for an R&M Improvement Program and has specified the program objectives. Chapter Two provides an overview of the entire program, describes the management and technical approaches to be utilized, describes each phase of the program in terms of the tasks to be accomplished in each phase, and identifies the expected benefits of the program. Chapter Three describes the organization for conducting the program and defines the functions and responsibilities of each participating organization. Chapter Four describes the specific activities to be undertaken by each program participant and the schedule for completion of each activity.

Appendix A describes, from an R&M point of view, equipment-acquisition approaches identified during Phase I of the program. Appendix B summarizes the use of R&M technology in the U.S. merchant fleet, as well as the R&M practices and procedures of selected European Certification Societies related to shipboard electronic equipment.

## CHAPTER TWO

### PROGRAM DESCRIPTION

#### 2.1 PROGRAM SCOPE

The R&M Improvement Program is a multi-year program consisting of four development phases. The general goals of the program are to improve the reliability and maintainability of shipboard equipment used in the U.S. merchant fleet, and to assist the U.S. merchant shipping industry in establishing certification and acquisition procedures that adequately address R&M requirements for future shipboard equipment. Because shipboard electronic equipment has been defined as an area of immediate concern by the merchant shipping community, electronic navigation and engine room control equipment will receive initial attention in the program.

Phase I of the program, which started in April 1976, had as its major objective the preparation of a Program Management Plan. With the publication of this plan, Phase I of the program has been completed.

The four development phases of the program, with associated time periods and major phase objectives, are identified in Table 2-1. A more detailed description of the activities to be performed in each phase is provided in Section 2.3.

#### 2.2 PROGRAM MANAGEMENT AND TECHNICAL APPROACH

##### 2.2.1 Management Approach

It is essential to the success of the R&M Improvement Program that it be a joint effort between the U.S. merchant shipping industry and the Maritime Administration. It is recognized by the Maritime Administration that the U.S. merchant shipping industry is engaged primarily in ocean shipping to produce a profit and that any proposed R&M Improvement Program must contribute to that objective.

A basic goal of the R&M Improvement Program is to make the U.S. maritime industry more competitive by reducing the life-cycle costs of shipboard equipment through improved



Table 2-1. R&M IMPROVEMENT PROGRAM PHASES AND OBJECTIVES			
Phase	Time Period	Major Phase Objectives	Subobjectives
I	April 1976 - April 1977	Develop the R&M Improvement Program Management Plan	Identify R&M technology in use in U.S. merchant fleet
II	May 1977 - April 1978	Prepare the Pilot Program Plan	Select a preferred R&M concept or combination of concepts for implementation in the U.S. merchant fleet
III	May 1978 - July 1979	Conduct the Pilot Program and prepare the Fleet-Wide Implementation Plan	Implement the Pilot Program  Evaluate Pilot Program results  Revise R&M procedures to make them applicable on a fleet-wide basis
IV	August 1979 - continuing	Implement the R&M Improvement Program in the U.S. merchant fleet on a permanent basis	Modify the R&M procedures on a continuing basis to accommodate changing requirements

equipment reliability and maintainability. This goal can be achieved only if the maritime industry becomes intimately involved in the development phases of the program so that it can advise MarAd on the commercial soundness of the program.

To ensure that the needs and resources of the industry are considered during the conduct of the program, an R&M Steering Committee will be formed under the auspices of the American Bureau of Shipping (ABS) shortly after Phase II of the program begins (April 1977). The Steering Committee will function in many ways, including advising MarAd on the feasibility of implementing the R&M concepts and procedures developed during the program.

The ABS is the pre-eminent private organization by which the structural integrity of U.S. vessels is assured and by which quality control procedures to be exercised over ship machinery are enforced. The rules of the ABS do not place quantitative reliability or maintainability requirements on marine systems, however, and they are silent as to electronic navigation or communications equipment. The R&M Improvement Program can assist the ABS in establishing rules and procedures to ensure that the equipment to be installed aboard U.S. vessels has acceptable R&M characteristics.

The committee structure of the ABS can provide an ideal vehicle for the establishment of the R&M Steering Committee to guide the direction of the R&M Improvement Program. Like the present committees of the ABS, the R&M Steering Committee should be composed of senior personnel from government and industry with an interest in marine equipment reliability and maintainability.

The functions and responsibilities of the R&M Steering Committee are described in Chapter Three.

The Maritime Administration will provide technical consulting services to the program through Phases II and III, which include operation of the Pilot Program, evaluation of test results, and preparation of the Implementation Plan to introduce the preferred R&M concept and procedures on a fleet-wide basis. The functions and responsibilities of MarAd are described in Chapter Three, and the activities to be performed by MarAd during each phase of the program are described in Chapter Four.

The Pilot Program to be conducted during Phase III will require the collection by shipboard personnel of R&M data on electronic equipment actually in use aboard U.S. merchant vessels. The participating carriers, who will be members of the R&M Steering Committee, will be invited to participate on the basis of their available resources, the particular types of electronic equipment aboard their vessels, and the trade routes they serve.

Each carrier will collect R&M data on his own equipment. In addition, carriers will have the benefit of analyses performed over the larger population of equipment in use by all participating carriers. The number of steamship companies that will participate in the Pilot Program will be determined during Phase II.

At the conclusion of the Pilot Program (Phase III), the ABS will be in a position to perform the actions necessary to implement the R&M Improvement Program on a U.S. merchant fleet-wide basis. The ABS and the merchant shipping industry, through their involvement in the R&M Steering Committee, will be knowledgeable of the R&M concepts that will be used and of the requirements for the management, administrative, and technical functions necessary to support an ongoing R&M program within the industry.

#### 2.2.2 Technical Approach

The technical approach to be utilized in the R&M Improvement Program will address two basic technical issues: (1) how to improve the reliability and maintainability of equipment currently in use, and (2) how to ensure that new equipment to be acquired has the requisite reliability and maintainability characteristics.

##### 2.2.2.1 R&M Improvement of Equipment in Use

The need for R&M improvement of equipment in current use is established by the demonstration of inadequate reliability or maintainability during operation. Equipment reliability can be quantified by recording the incidences of equipment failure as well as the repair time necessary to return the equipment to satisfactory operation.

Through careful monitoring of equipment failure and repair actions, the user has the opportunity to take action to improve equipment reliability and maintainability. These actions may include at-sea or on-shore modifications to the equipment, adjustments to spare-parts levels on board, changes to maintenance procedures, changes to technical documentation, or a combination of these actions.

Figure 2-1 illustrates the activities relating to reliability and maintainability that are undertaken during the life of an equipment. The cycle begins with the definition of the operational requirements in terms of the functions to be performed by the equipment, its physical requirements (size and weight), its reliability and maintainability requirements, its environmental requirements, and possibly its cost.



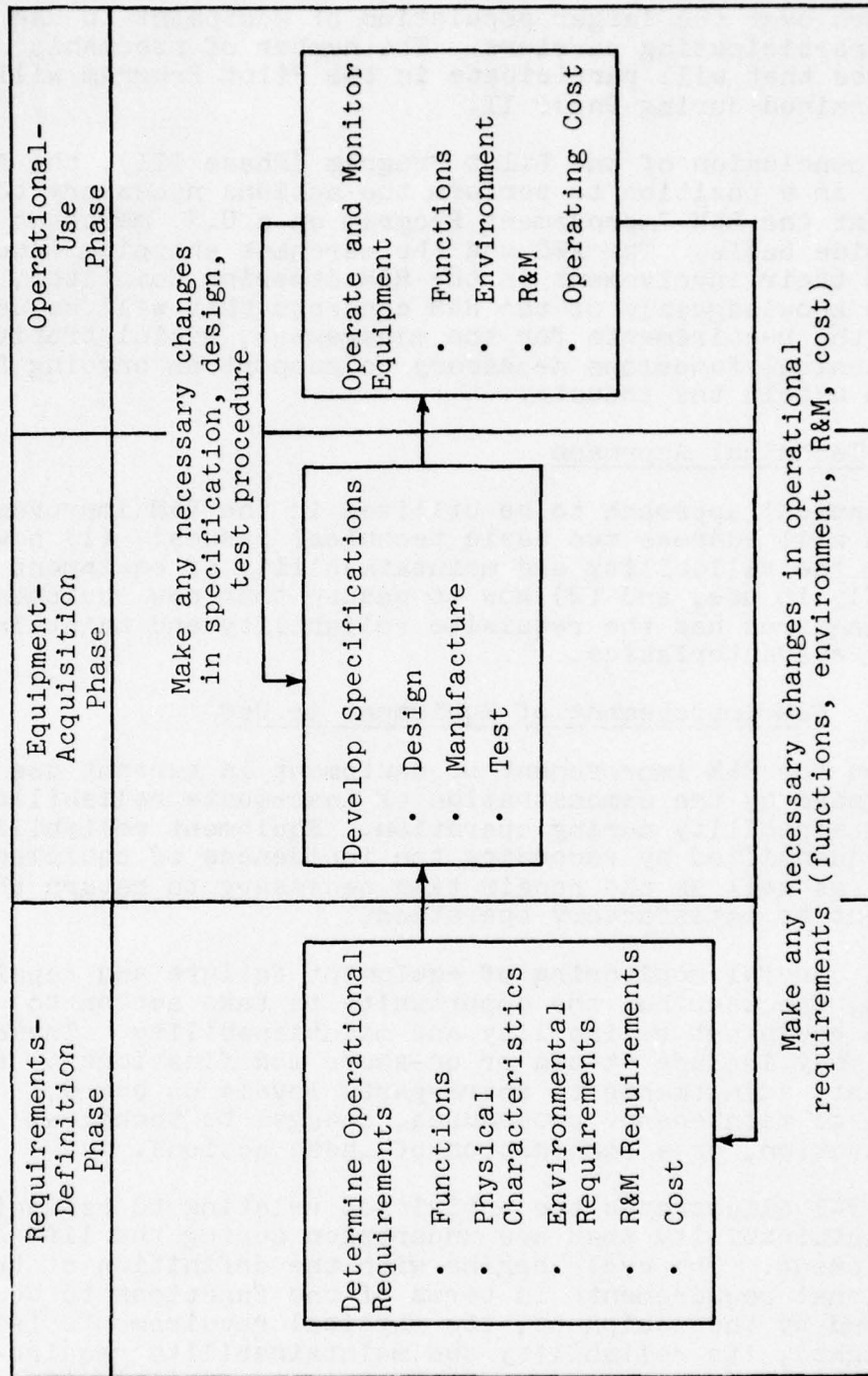


Figure 2-1. R&M ACTIVITIES RELATED TO EQUIPMENT ACQUISITION AND USE



Although these requirements are often specified by the user or purchaser, in the maritime industry the equipment suppliers usually determine these requirements and offer the equipment to the user on an "off the shelf" basis. The user must then determine if the equipment being offered satisfies his requirements. An important point is that it is usually the user who suffers the ill effects of inherently poor equipment performance or reliability.

#### 2.2.2.2 R&M Considerations for Future Generations of Equipment

The activities outlined for Phase II of the R&M Improvement Program in Section 2.3.2 (i.e., Select the R&M Improvement Concept, Develop Procedures, and Prepare the Pilot Program Plan) will address all phases of equipment development and operation. As a starting point, the R&M Improvement Program will first consider equipments that are operational in ships and thus will examine the life cycle of those equipments during their operational-use phase. A primary reason for this approach is that there is a possibility of immediate near-term user benefit, assuming that some recommended reliability improvements can be implemented. In addition, an R&M data collection and analysis system can be brought into use that is not only necessary to the systematic improvement of present equipment, but is also essential to the longer-range program of accurately determining the R&M requirements for future generations of equipment. Through careful monitoring of equipment operation, the user has the opportunity to make necessary adjustments to equipment specification, testing, and manufacturing or maintenance procedures. In the case of a user purchasing "off the shelf" equipment, he has the opportunity to influence his supplier in the design and manufacture of the equipment already in use and to affect the supplier's design and manufacturing processes for future generations of equipment.

Candidate equipment acquisition approaches that incorporate R&M requirements are described in Appendix A to this Program Plan. They include the Commercial Airlines Acquisition Methodology, Military Specifications and Standards, and Type Approval. (The Type Approval approach is currently utilized in much of the maritime community.) These acquisition approaches will be analyzed during Phase II to select the most advantageous elements from each approach to formulate a preferred R&M concept. The application of a formal R&M concept, utilized throughout the U.S. merchant shipping industry on a consistent basis, combined with a fleet-wide R&M data collection and analysis system, will enable the

U.S. maritime community to establish the requirements that must be met to ensure that equipment aboard U.S. merchant vessels operates satisfactorily.

## 2.3 PROGRAM PHASE DESCRIPTIONS

Table 2-1 provided a summary description of the objectives of each phase of the R&M Improvement Program. The following sections provide a more detailed description of the work to be conducted during each phase. Specific activities and the organizations responsible for each program activity are detailed in Chapter Four.

### 2.3.1 Phase I: Development of the Management Plan for the R&M Improvement Program

Phase I of the R&M Improvement Program, now completed, had as its major objective the preparation of this Program Management Plan. As a basis for the preparation of this plan, MarAd has completed the following activities:

- Reviewed and assessed the applicability of the R&M experience and programs of the U.S. Navy and commercial transportation industries to the merchant shipping industry
- Investigated the R&M specification programs of foreign certification societies to determine the applicability of the procedures to the U.S. merchant shipping industry
- Identified the relationships of the several organizations within the merchant shipping industry having direct or indirect interest in improving the reliability of shipboard equipment
- Described the candidate alternative approaches to the specification of R&M requirements that may be applicable to the U.S. merchant shipping industry

The Phase I work conducted by MarAd also included the identification of R&M data base systems that might be utilized in support of a preferred R&M concept. The systems identified are the UK Atomic Energy Authority's Systems Reliability Service (SRS) data base, the MarAd Maintenance and Repair (M&R) System, and the Government Industry Data Exchange Program (GIDEP) managed by the U.S. Navy.



The findings and recommendations of Phase I of the program are summarized in Appendix B. The following reports were published by MarAd during Phase I:

- Summary Report - Status of Reliability and Maintainability Technology in Use in the U.S. Merchant Marine, September 1976, NMRC-KP-170.
- Reliability and Maintainability Practices Utilized by Selected European Certification Societies for Shipboard Electronic Equipments, October 1976.

2.3.2 Phase II: Select the R&M Improvement Concept, Develop Procedures, and Prepare the Pilot Program Plan

During Phase II, the features of the candidate R&M concepts identified during Phase I will be evaluated within the framework of existing U.S. merchant fleet methods and procedures. A single concept or, more likely, a combination of elements from various R&M concepts will be selected for implementation. Implementation procedures that describe the technical, management, and administrative activities will then be prepared.

In order to define the data collection and analysis requirements that support the preferred R&M concept, the data-base management systems identified during Phase I will be evaluated.

An operational model relating the factors of shipboard system availability to voyage cost will be developed. By the use of computer aids, the sensitivity of voyage cost to varying system-availability levels will be analyzed for a selected trade route, chosen on the basis of its importance in U.S. foreign trade. The likely route will be between U.S. east coast ports and northern European ports.

A Pilot Program Plan will be prepared to describe the activities required to implement the selected R&M concept. The Pilot Program will be executed during Phase III.

2.3.3 Phase III: Conduct of Pilot Program

An R&M Pilot Program will be conducted to validate the expected benefits of the preferred R&M approach developed during Phase II. The program will be centered on a selected equipment or system, such as a radar, for which data and information exist or can be relatively easily acquired, and in which the participating organizations have a significant interest from an operating and cost standpoint. The Pilot Program, to be conducted with the cooperation of the owners,

equipment suppliers, ABS, and others, will include the following activities:

- Collect from owners, users, and manufacturers available data and information on the selected equipments concerning problems, failure, repair costs, and downtime. Develop data from equipment and systems in use during normal operations.
- Collect available data, for appropriate comparison, on comparable equipments used in other applications, such as the military.
- Determine the existing R&M characteristics of the selected equipments and collect data throughout the Pilot Program to be utilized in the reliability improvement process.
- Review specifications and warranties used during acquisition of the selected equipments, particularly as related to reliability and maintainability.
- On the basis of data collected during the Pilot Program, identify areas in specifications and warranty documents that should be improved, changed or included to address R&M requirements more effectively.

Phase III will serve as a transition period, allowing MarAd to take a less dominant role and industry a more dominant role. The Pilot Program will have demonstrated the cost benefits that can be derived as well as the feasibility and desirability of the R&M Improvement Program.

During Phase III, an implementation plan will be prepared to introduce the R&M Improvement Program into the U.S. maritime industry on a fleet-wide, continuing basis. The actual fleet implementation of the program will take place during Phase IV.

#### 2.3.4 Phase IV: Implementation of the R&M Improvement Program

During Phase IV, the maritime industry will adopt and implement the R&M concepts and procedures that have been demonstrated to be most applicable. Adoption by the industry will create a permanent system administered by the ABS for specifying the reliability and maintainability criteria for shipboard equipment installed on U.S. merchant ships. This permanent system will include provisions for continuously assessing program effectiveness, updating specifications, and adopting additional specifications as dictated



by experience and as new equipments are introduced. During Phase IV, the process of including all critical equipments in the program should be under way and a significant improvement in the U.S. merchant fleet R&M will gradually be realized.

#### 2.4 PROGRAM BENEFITS

The following benefits are to be derived from the R&M Improvement Program.

- Equipment reliability will be increased, resulting in lower maintenance-repair costs.
- Lost time or downtime due to equipment failure will be diminished.
- Operations will be made safer as a result of improved equipment reliability. This benefit may be accompanied by lower insurance costs.
- The relationship between equipment reliability and voyage cost will be quantified, allowing shipping company management to make valid trade-off decisions involving equipment purchase cost versus maintenance and repair costs.
- A cooperative industry approach to reliability and maintainability will reduce the cost impact to each participating organization because all users will share the expense of establishing and operating the program. Conversely, the benefits of the program will be shared by all users.
- A consistent industry approach to equipment reliability and maintainability will be established, thus improving the bargaining power of the marine industry with respect to marine equipment suppliers.

## CHAPTER THREE

### ORGANIZATION AND MANAGEMENT

#### 3.1 PROGRAM ORGANIZATION

The major participants in the R&M Improvement Program are the American Bureau of Shipping, the maritime industry organizations represented on the R&M Steering Committee, and the Maritime Administration. Because the R&M Steering Committee, formed under the auspices of the ABS, will provide the coordinating interface between the merchant shipping community and MarAd during the course of the program, the Committee is also identified as a major program participant and its functions and responsibilities are defined.

The specific activities to be undertaken by each program participant, as well as major milestones and events, are described in Chapter Four.

The Maritime Administration will manage the R&M Improvement Program through Phase III, "Conduct of the Pilot Program and Preparation of the Fleet-Wide Implementation Plan", and will provide technical support to the program.

The R&M Steering Committee will evaluate the results of the R&M Improvement Program as work progresses to ensure that the requirements identified and the intermediate plans developed serve the needs of the industry and are within the resources of the industry to implement.

The steamship companies that participate in the Pilot Program will provide the means for recording R&M data on ship-board equipment in actual use in their respective fleets. The procedures to be utilized in the data recording, compilation, and analysis process will be specified in the Pilot Program prepared during Phase II.

### 3.2 FUNCTIONS OF PARTICIPATING ORGANIZATIONS

The following sections describe the functions of organizations participating in the program. Specific activities to be performed by each organization are described in detail in Chapter Four, which also provides a schedule showing the chronological relationship of program activities.

#### 3.2.1 The Maritime Administration

The following functions are to be performed by the Maritime Administration:

- Act as the central management authority for the program through Phases II and III.
- Provide technical support to the program in the field of reliability engineering through Phases II and III (the technical activities to be performed by MarAd are described in Chapter Four).
- Interface with Government agencies such as the U.S. Coast Guard and the Federal Communications Commission to ensure that these agencies are apprised of the results of the R&M Improvement Program.
- Review internal MarAd policies and procedures to ensure that such policies and procedures are consistent with and supportive of the objectives of the R&M Improvement Program.

MarAd will also coordinate the findings and recommendations of the program with the State Department to ensure that the U.S. position taken before international regulatory agencies such as the Intergovernmental Marine Consultative Organization (IMCO) and the International Electrotechnical Commission (IEC) are consistent with the findings and recommendations of the program.

#### 3.2.2 The American Bureau of Shipping (ABS)

The following functions are to be performed by the ABS:

- Form the R&M Steering Committee within the ABS Committee structure upon commencement of Phase II of the program.
- Perform the necessary secretariat functions to ensure efficient communication between the Committee members. The function includes such administrative activities as the scheduling of committee meetings, preparation of agenda, and preparation and disseminating of meeting minutes.



- Provide the physical facilities necessary for committee meetings when held at the New York headquarters of the ABS.
- Regularly disseminate public information about the goals, objectives, and results of the program.
- Upon completion of the Pilot Program and a determination by the ABS of the validity of the R&M procedures that have been developed during the program, introduce into the "Rules" of the ABS those requirements which are found to be necessary to assure adequate reliability and maintainability of equipment aboard U.S. merchant vessels.

### 3.2.3 The R&M Steering Committee

The R&M Steering Committee will be composed of senior-level representatives of all segments of the maritime community that have an interest in the reliability and maintainability of marine equipment. These segments will include ship owners/operators, shipbuilders, ship design agents, marine underwriters, the U.S. Coast Guard, and the Maritime Administration. The ABS will assign one of its staff members to serve on the Committee.

The following functions are to be performed by the R&M Steering Committee:

- Act as the central coordinating agency of the program, providing the interface between MarAd and the merchant shipping industry.
- Evaluate the technical reports and recommendations developed by MarAd during the program. These reports are identified in Chapter Four.
- Encourage participation by steamship companies in the Pilot Program to be conducted during Phase III.
- Evaluate reports received during the Pilot Program (Phase III) and, if applicable, recommend to the ABS and participating steamship companies those actions which can be undertaken in the short term to produce an immediate improvement in the reliability and maintainability of equipment currently in use. These actions may include recommended changes in:
  - Equipment design
  - Component selection
  - Specifications

- • Testing procedures
- • Manufacturing procedures
- Upon completion of the Pilot Program and evaluation of results, recommend to the ABS, the USCG, and MarAd those changes in the rules and regulations of these respective organizations which are necessary to assure high reliability of equipment in use, as well as to ensure that future generations of shipboard equipment will possess required R&M characteristics.

#### 3.2.4 Participating Steamship Companies

The participating steamship companies will become active participants in the program during the conduct of the Pilot Program (Phase III). Steamship companies will be represented on the R&M Steering Committee and will participate in the review of technical reports and recommendations presented to the Committee during Phase II.

The following functions are to be performed by the participating steamship companies:

- Participate in the Pilot Program (Phase III) by collecting R&M data on selected equipments during actual shipping operations and transmitting the data to MarAd for analysis. The participating carriers will issue instructions to shipboard personnel through their respective marine superintendents to collect and forward the data in accordance with the Pilot Program Plan agreed upon during Phase II.
- Evaluate reports received from MarAd during the course of the Pilot Program pertaining to the results of the R&M analysis of the equipment being monitored and, if appropriate, take actions that may be necessary to improve equipment R&M within their respective fleets.

## CHAPTER FOUR

### SCHEDULED ACTIVITIES

This chapter describes the scheduled activities for the remainder of the R&M Improvement Program -- Phases II, III, and IV. By these activities, the program objectives described in Chapter One and the objectives of each phase described in Chapter Two will be attained.

Figure 4-1 shows the specific activities that must take place during Phases II, III, and IV of the program as well as the Phase I activities already completed. As requirements change as a result of accumulated experience during program execution, Figure 4-1 will be revised. The activity descriptions presented in the following paragraphs are keyed to the phase number and letter identifiers shown in Figure 4-1.

#### 4.1 PHASE II ACTIVITIES

During Phase II the preferred R&M concept will be selected, implementation procedures will be developed, and the Pilot Program Plan will be prepared. Various candidate R&M and marine-equipment acquisition management concepts will be studied within the framework of existing U.S. maritime industry structure and methods. A single R&M concept or a combination of elements from various concepts will be developed as the approach for the R&M Improvement Program. The approach will include management and data requirements.

At the end of Phase II, the Pilot Program Plan will be coordinated by MarAd with the R&M Steering Committee. The R&M Steering Committee will thereby have the opportunity to recommend modification to the Phase III Pilot Program.

##### 4.1.1 Activity II-A: Formulate the R&M Steering Committee

Responsibility: ABS

Performance Period: April 1977 through June 1977

MarAd will present this Program Management Plan, together with the results of Phase I background, to the ABS for its evaluation and comments. The ABS may recommend changes



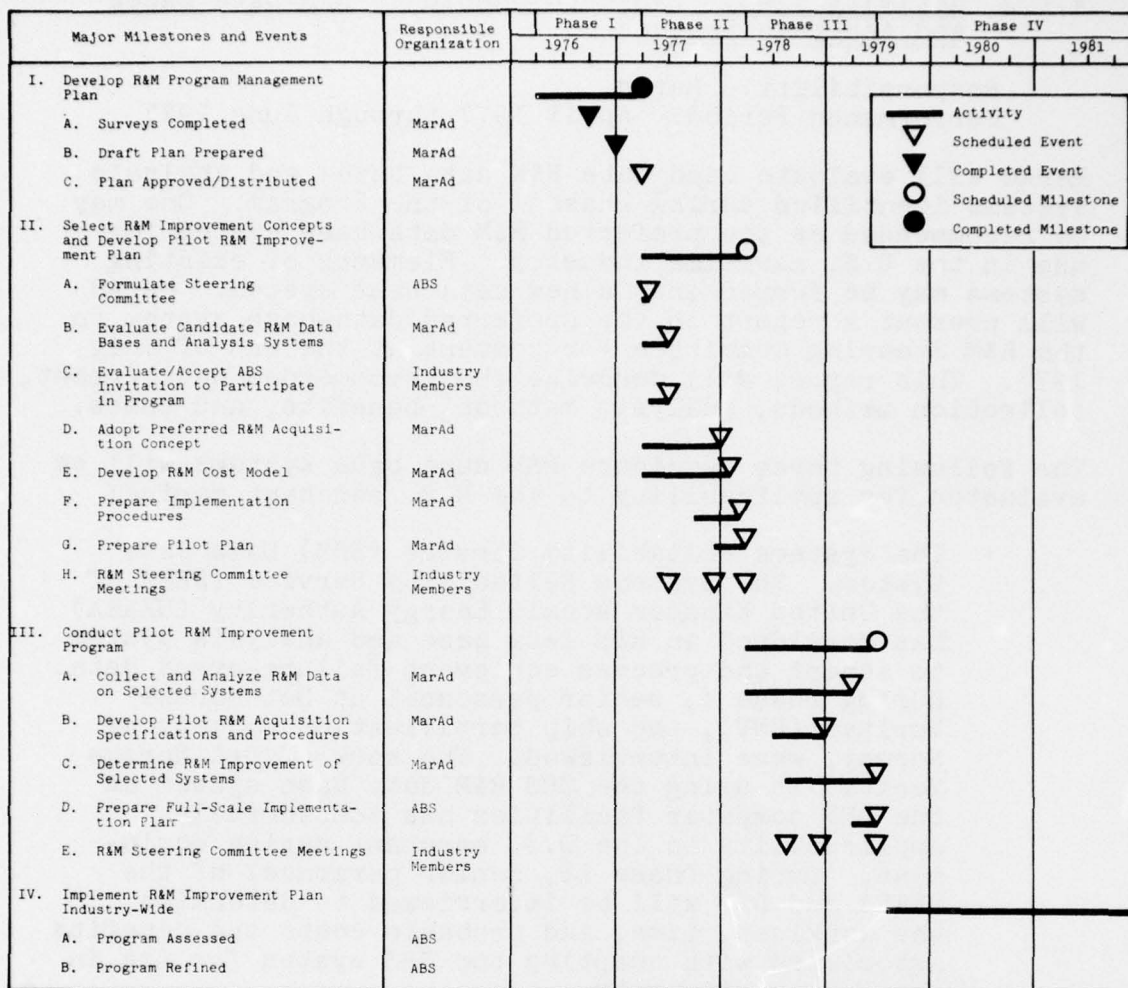


Figure 4-1. RELIABILITY AND MAINTAINABILITY IMPROVEMENT PROGRAM: ACTIVITIES SCHEDULE

to make the plan accommodate the ABS organizational framework and procedures more closely.

When the Management Plan has been completed, the ABS will invite members of the U.S. maritime industry to form the R&M Steering Committee. Members accepting the invitation will be asked to attend the initial Committee meeting scheduled for late June 1977. The ABS will itself be represented on the Committee. The invitation will include a copy of this Program Management Plan and a request for an early response. If more interested industry members respond than can be accommodated, the size of the Committee and the organizations to be represented will be resolved jointly by the ABS and MarAd.

#### 4.1.2 Activity II-B: Evaluate Candidate R&M Data Bases and Analysis Systems

Responsibility: MarAd

Performance Period: April 1977 through June 1977

MarAd will evaluate candidate R&M data bases and analysis systems identified during Phase I of the Program. One may be recommended as the preferred R&M data base system for use in the U.S. maritime industry. Elements of existing systems may be formed into a new data base system. MarAd will present a report on the preferred data-base system to the R&M Steering Committee for comment at the end of July 1977. This report will describe the recommended data format, collection methods, analysis methods, benefits, and costs.

The following three candidate R&M data base systems will be evaluated for applicability to the U.S. merchant marine:

- The Systems Reliability Service (SRS) Data Base System. The Systems Reliability Service (SRS) of the United Kingdom Atomic Energy Authority (UKAEA) has developed an R&M data base and analysis system to accept and process equipment failure-event data. During Phase I, senior personnel at Det Norske Veritas (DNV), the ship certification society of Norway, were interviewed. The work of Det Norske Veritas in using the SRS R&M data base system on the DNV computer facilities has considerable applicability to the U.S. merchant marine equipment. During Phase II, senior personnel of the UKAEA and DNV will be interviewed to determine the workload, time, and probable costs and benefits associated with adapting the SRS system for use in the U.S. environment.
- The Government Industry Data Interchange Program (GIDIP). The GIDIP is a service that is operated and managed by the U.S. Navy to allow the interchange of technical data between government and industry. The potential benefits of participation in GIDIP, which involve the sending and receiving of equipment R&M data by participating organizations, will be evaluated.
- The MarAd Maintenance and Repair Data Base System. MarAd maintains a data base on the repairs to U.S. flag vessels that are operating under the U.S. maritime subsidy program. The MarAd system is oriented primarily to repair cost; however, the system elements used for equipment and vessel identification will be examined to determine

their ability to satisfy the data requirements in support of the preferred R&M concept. The MarAd repair-data base may also be effectively used as a means to determine the most advantageous approach, from a profit standpoint, to choosing the class of equipment that will receive initial attention in the R&M Improvement Program.

The report describing the preferred data base and analysis system will be submitted to the committee members for comment by early July 1977.

4.1.3 Activity II-C: Evaluate/Accept ABS Invitation to Participate in the Program

Responsibility: Industry Members  
Performance Period: May and June 1977

In response to the ABS invitation to form an R&M Steering Committee, each potential industry member must determine his level of interest in the program and willingness to participate. Steamship companies, shipbuilders, naval architects, equipment suppliers, marine underwriters, government agencies, and professional societies will be invited to participate in the program. The ABS will schedule the time and place for the first meeting of the R&M Steering Committee.

4.1.4 Activity II-D: Adopt Preferred R&M Improvement Concept

Preparation Responsibility: MarAd  
Adopting Responsibility: R&M Steering Committee  
Performance Period: April 1977 through December 1977

MarAd will analyze candidate R&M concepts and recommend a preferred concept or combination of elements from candidate concepts for implementation in the Pilot Program. The R&M concept ultimately selected may be a new concept that has not been used previously in the merchant shipping or other transportation industries. It will encompass the requirements associated with equipment specification and acquisition, R&M data collection, and reliability improvement. The concept will thereby be related to the entire life cycle of the equipment.

In the performance of this task, MarAd will establish applicability criteria for alternative R&M concepts and will examine each concept in terms of its benefit to U.S. merchant shipping. The data requirements and the management requirements for implementing the preferred R&M concept will be described.



By early November 1977 MarAd will deliver a report describing the preferred R&M concept to the ABS, which in turn will distribute the report to the members of the R&M Steering Committee as described in activity II-H.

4.1.5 Activity II-E: Develop a Model of System Availability versus Voyage Cost

Preparation Responsibility: MarAd

Adopting Responsibility: R&M Steering Committee

Performance Period: April 1977 through January 1978

MarAd will develop an operational model to relate shipboard system availability to voyage cost on a selected trade route. The voyage profiles and the maintenance strategies employed on the trade routes to be studied will be defined. The shipboard system that are voyage-critical, including those necessary for ship propulsion and navigation and for cargo-handling, will be determined. Voyage-associated costs that are time-dependent, such as personnel, pilotage, wharfage, and stevedoring, will be identified. Model logic will be developed that allows system R&M to be varied and its effect on availability and voyage cost to be determined. Existing operational and R&M data for use in exercising the model will be collected. The data base from U.S. Navy ships, as well as data bases maintained by commercial organizations, including European certification societies will be evaluated for use in exercising the model. The results of the effort will be coordinated with the merchant shipping industry through the Steering Committee to show the value of the model in measuring the sensitivity of system availability to voyage cost.

MarAd will present the results of the analysis to the R&M Steering Committee at the meeting of April 1978 described in activity II-H.

4.1.6 Activity II-F: Prepare Implementation Procedures

Responsibility: MarAd

Performance Period: July 1977 through January 1978

MarAd will prepare the procedures to be used in full-scale implementation of the preferred R&M concept. These procedures will describe the participation by MarAd, the ABS, and other members of the U.S. maritime industry and specify the reporting structure and methods. MarAd will develop the technical, management, and administrative implementation procedures describing the data collection, analysis, and dissemination process. The equipment specification and testing techniques will also be described.

MarAd will present its recommendations to the April meeting of the R&M Steering Committee described in activity II-H and will supply Committee members with a report describing the preferred R&M concept at least one month before the meeting.

#### 4.1.7 Activity II-G: Prepare the Pilot Program Plan

Responsibility: MarAd

Performance Period: January 1978 through April 1978

MarAd will prepare the plan to formulate and control the Pilot Program to be implemented during Phase III. This program will validate the expected benefits of the preferred R&M concept developed during Phase II, and will encompass several activities. During the Pilot Program, MarAd will collect from owners, users, and manufacturers available data and information on the selected equipments concerning problems, failures, repair costs, and downtime. Data will also be obtained from equipment and systems during normal use. Available data on comparable equipments used in other applications, such as the military, will be collected.

Through the use of the preferred data base and analysis system, the existing R&M characteristics of selected equipments will be determined. MarAd will review the specifications and warranties used during acquisition of the selected equipments, particularly as related to R&M requirements.

The areas in specifications and warranty documents that should be improved, changed, or included to address R&M requirements more effectively will be identified, and the R&M characteristics identified for the selected equipments will be compared with those expected to be achieved by means of improved specifications and warranty documents. The benefits of improved specifications or warranty documents and acquisition processes will be determined. Pilot specifications and related documents for the selected equipments will be developed. The specifications will be coordinated with owners, users, manufacturers, and certification societies to determine impact. MarAd will determine procedures for developing, reporting, retaining, and analyzing the data for a continuing merchant fleet R&M program.

The Pilot Program Plan will identify the criteria to be used in evaluating the Pilot Program results. The data collection and evaluation system recommended for ultimate use throughout the merchant fleet will be employed in the Pilot Program.

The Pilot Program Plan will be the final product of Phase II. MarAd will present the plan to the R&M Steering Committee for comment and recommendations during the April 1978 meeting as described in activity II-H. MarAd will supply Committee members with a draft of the Pilot Program Plan at least one month before the meeting. Upon plan approval, the Steering Committee will ratify the continuation of the R&M Improvement Program into Phase III.

4.1.8 Activity II-H: Phase II R&M Steering Committee Meetings

Responsibility: MarAd

Performance Period: 1 July 1977 (First Meeting)  
1 December 1977 (Second Meeting)  
1 April 1978 (Third Meeting)

MarAd will request the ABS to call the first R&M Steering Committee meeting in early July 1977. As the first order of business, the Committee will elect a permanent chairman. During the first meeting, MarAd will report on the background and progress of the R&M Improvement Program. This Program Management Plan will be presented. The rules and procedures of all future meetings will be formulated and adopted. To increase meeting efficiency, MarAd will provide all participants with pertinent documentation at least one month before each meeting.

The permanent chairman will call and chair the second meeting of the R&M Steering Committee early in December 1977. During the second meeting, the committee will review program progress. Specifically, it will review the R&M data base and analysis system recommended under activity II-B and the R&M improvement concept recommended under activity II-E. Pertinent documentation will be provided to the industry participants by MarAd at least one month prior to the meeting.

The permanent chairman will call the third meeting of the R&M Steering Committee early in April 1978, at which time the Committee will review the R&M model developed by MarAd in activity II-F. The model relates system availability to voyage cost. The Committee will also review the Pilot Program Plan prepared under activity II-G. Most important, the R&M Steering Committee will assess the expected cost and benefits established for the program and decide whether the progress of the program justifies the Phase III effort described in the Pilot Program Plan.



## 4.2 PHASE III ACTIVITIES

The Phase III activities are presented in this Program Management Plan in outline form. The Phase II Pilot Program Plan will present detailed Phase III activities based on the results of Phase II activities and approval of the R&M Steering Committee. The Phase III activities are likely to change in both scope and function as the program progresses through Phase II.

In cooperation with the ABS and participating steamship companies, MarAd will conduct an R&M Pilot Program to demonstrate the expected benefits of the preferred R&M concept developed during Phase II. The Pilot Program will concentrate on previously selected equipment. R&M data will be collected by ship operators and submitted to MarAd for analysis. A monthly progress report of the Pilot Program will be sent to the committee members by MarAd.

At the end of the Pilot Program, the plan for implementing the full-scale R&M Improvement Program will be prepared by MarAd and presented to the R&M Steering Committee for approval. Upon approval, the committee will have ratified the continuation of the program into Phase IV and a decision will have been made relative to management and control of the remainder of the program.

### 4.2.1 Activity III-A: Collect and Analyze Data

Responsibility: MarAd, Steamship Companies

Performance Period: April 1978 through April 1979

In accordance with the organization and procedures defined in the Phase II Pilot Program Plan, MarAd will collect from owners, users, and manufacturers available data and information on the selected equipments concerning problems, failures, repair costs, and downtime. Data will also be developed from equipment and systems used during normal operations. MarAd will collect available data, for appropriate comparison, on comparable equipments used in other applications such as the military.

Steamship companies participating in the Pilot Program will collect shipboard data on the selected equipments from June 1978 through January 1979 in accordance with the system and procedures set forth in the approved Pilot Program Plan and transmit these data to MarAd for analysis. The results of the R&M analysis will be transmitted by MarAd to the ABS, R&M Steering Committee members, and participating carriers.

The progress of the data collection and analysis functions performed to date will be presented by MarAd to the second R&M Steering Committee meeting in December 1978.

The results of the Pilot Program will be presented to the R&M Steering Committee for approval during the meeting scheduled for July 1979. Activity III-G gives details of the meeting.

4.2.2 Activity III-B: Develop Pilot R&M Acquisition Specifications and Procedures

Responsibility: MarAd

Performance Period: June 1978 through December 1978

On the basis of the preliminary Pilot Program results, MarAd will review the R&M-related specifications and warranties used during acquisition of the selected equipments. From data collected during the Pilot Program, MarAd will identify equipment improvements or changes, to specifications and warranty documents that will address R&M requirements more effectively.

MarAd will present preliminary pilot specifications to the second Phase III meeting of the R&M Steering Committee during December 1978 for review and comment. This review will enable MarAd to include draft specifications as attachments to the full-scale implementation plan to be presented to the Steering Committee in July 1979.

Coordination of the preliminary R&M specifications and procedures within the industry will enable owners, users, manufacturers, and certification agencies to assess impact. The industry will respond to MarAd with an assessment of the feasibility of applying the preliminary specifications and procedures.

4.2.3 Activity III-C: Determine the R&M Improvement of the Selected Equipment

Responsibility: MarAd

Performance Period: August 1978 through April 1979

MarAd will collect and analyze data throughout the Pilot Program to determine the R&M characteristics of existing equipment. During the Pilot Program, corrective actions will be taken to improve reliability and maintainability on the selected equipment. The effect of these actions will be measured throughout the R&M data collection process.

In addition, R&M benefits that might be realized with improved specifications of warranty documents will also be estimated. The results of the R&M improvement effort will be reported to the Committee via the monthly progress report, as well as the final report to be presented at the Committee meeting in July 1979.

4.2.4 Activity III-D: Prepare Full-Scale Implementation Plan

Responsibility: ABS

Performance Period: April 1979 through July 1979

An Implementation Plan will be prepared to apply the preferred R&M approach to additional ship systems and equipments. This plan will address priorities for the equipments to be included in the program and will set forth the activities to be conducted as well as technical and management responsibilities. The schedule for implementation will also be part of the plan. The plan will be presented to the R&M Steering Committee at its meeting in July 1979.

4.2.5 Activity III-E: Phase III R&M Steering Committee Meetings

Responsibility: MarAd

Performance Period: August 1978 (First Meeting)  
December 1978 (2nd Meeting)  
July 1979 (Third Meeting)

The permanent chairman will call the first meeting in Phase III during August 1978. MarAd will report on the progress of the Pilot Program. The R&M Steering Committee will review progress and will evaluate available data for the selected systems.

The permanent chairman will call and chair the second meeting in Phase III during December 1978. MarAd will report the results of the Pilot Program to date, including any R&M improvement that may have resulted from recommended actions. MarAd will also report on the results of exercising the model developed during Phase II with Pilot Program data collected during Phase III.

At the third meeting in Phase II, called for July 1979, the ABS will play a greater role in the Program and MarAd a lesser role. A decision on the future responsibilities of the R&M Steering Committee as it relates to the standing ABS Committee structure will likely be made at this time.



The Committee will review the MarAd report of the Pilot Program and the Full-Scale Implementation Plan. Adoption of the report of Pilot Program results and the Full-Scale Implementation Plan will constitute a decision to proceed to Phase IV.

#### 4.3 PHASE IV ACTIVITIES

At this time it is possible only to outline the Phase IV activities. The Phase III Implementation Plan will present detailed Phase IV activities based on the experience acquired during Phases II and III.

Under the auspices of the ABS, the U.S. maritime industry will adopt and implement the full-scale R&M Improvement Program industry-wide. The R&M concepts and procedures adopted will be those which have demonstrated the greatest benefits to the industry during the Phase III Pilot Program. The industry will have established a permanent full-scale system for specifying the reliability and maintainability of shipboard equipments. During Phase IV, the industry will include within the program all critical equipments and can thereby achieve significant R&M improvement in the U.S. merchant fleet.

##### 4.3.1 Activity IV-A: Assess Program

Responsibility: Maritime Industry

Performance Period: June 1979 and continuing indefinitely

The U.S. maritime industry will have adopted the R&M concepts and procedures that have proven beneficial. They will establish procedures for specifying and improving system reliability and maintainability in the maritime industry. The program will be continuously assessed for effectiveness.

##### 4.3.2 Activity IV-B: Update Program on a Continuing Basis

Responsibility: ABS

Performance Period: June 1979 and continuing indefinitely

As experience dictates, the ABS R&M Committee will update and adopt new specifications as new equipments are introduced. All critical equipments will be added to the R&M Improvement Program and the benefits to the U.S. maritime industry assessed.

## APPENDIX A

### CANDIDATE APPROACHES TO EQUIPMENT ACQUISITION

The equipment acquisition approaches described in this appendix were identified during Phase I of the R&M Improvement Program. In selecting a preferred R&M concept for the U.S. merchant shipping industry, MarAd will study these candidate acquisition approaches to determine if a particular approach or a combination of elements from candidate approaches can be effectively utilized within the R&M concept ultimately selected for implementation in the U.S. merchant fleet.

#### 1. COMMERCIAL AIRLINE ACQUISITION METHODOLOGY (CAAM)

The commercial airline acquisition methodology (CAAM), developed primarily for the procurement of avionic equipment, has provided the U.S. airline industry with high-quality equipment at reasonable prices. For example, a comparison of Air Force and commercial airline instrument landing systems of similar performance, characteristics, and age indicates that airline equipment costs about half as much as military equipment while its reliability is about twice that of military equipment. The process depends on the existence of competition throughout the useful life of the equipment. The CAAM involved three major participants: the customer (airline companies); the supplier (hardware manufacturers); and the technical specialist, Aeronautical Radio, Inc. The process has evolved over the past 35 years and operates in a highly competitive open forum. The major features of the CAAM are described in the following paragraphs.

##### 1.1 Specification of Equipment on a "Form-Fit-Function" Basis

"Form-fit-function" implies the combination of interface and functional specifications that precisely and completely address required mechanical, electrical, and environmental interfaces, together with the required equipment functions and performance. Details of internal design are not specified. The form-fit-function approach to equipment specification has the advantage that while the interface is

standardized, the internal configuration of the unit can evolve as technology changes, taking advantage of new materials. Moreover, interchangeability between old and new generations of electronics becomes a practical reality, and the need for modification of an installation to accommodate the new equipment is eliminated. With interface standardization, production costs can be held down by competition among interchangeable designs, and new systems can be synthesized from proven standard units.

### 1.2 Use of Warranty Provisions

The following general types of warranty or guarantee are used:

- Standard Warranty. The material is guaranteed to be free from defects in material, workmanship, and design, and is suitable for its intended use.
- Ultimate Life Warranty. Applies to major structural components (e.g., hull), guaranteeing freedom from failure for a specified number of operating hours.
- Reliability Guarantee. An agreement between supplier and buyer that the mean time between failures (MTBF) of the equipment will not be less than a specified value. The required MTBF must be reached within an agreed-upon time and must be sustained for an agreed-upon operating period.
- Maximum Parts Cost Guarantee. Agreement between buyer and seller stipulating the maximum parts per operating hour for maintaining, modifying, repairing, and overhauling selected equipment.

### 1.3 Coordination and Publication of Equipment Specifications on an Industry-Wide Standardization Basis

To blend operations, maintenance, and engineering expertise for the benefit of the industry as a whole, as well as for individual members, the airlines established the Airlines Electronics Engineering Committee (AEEC). The committee is the consequence of the foresight of airline pioneers in recognizing the potential within the industry for industry-wide specification writing as the only alternative to continuing proliferation of airline specification writing by the U.S. Government. Thus, in 1949, the AEEC was established.

The primary task of the AEEC is to coordinate the preparation of ARINC "Characteristics" (or specifications), which promulgate to prospective manufacturers of airline electronic equipment the opinions of the airline technical people on the



requirements for new equipment. These characteristics, prepared in an open forum, also help to channel new equipment designs in a direction that can produce maximum possible standardization of physical and electrical characteristics without seriously hampering engineering initiative. With its broad spectrum of technical participation, the AEEC has remained a dynamic body during the more than 25 years of its existence.

The full committee consists of 22 voting members. Many interested parties, representing wide public interest, attend the meetings. Recent typical attendance has exceeded 300 contributing observers from airlines, governmental regulatory groups, military agencies, avionics and airframe manufacturers, and members of the press.

#### 1.4 Resolution of Common Maintenance Problems Through an Industry Forum Approach

A forum is provided by the airline industry for discussing and resolving maintenance problems of common concern to participating organizations. The committee, called the Airlines Electronic Maintenance Committee (AEMC), operates through an elected steering group and appointed task groups that provide a continuous medium for the exchange of information among avionics users, installers, manufacturers, and maintenance specialists. Its objectives are to promote improved electrical systems and equipment and increase the reliability and performance of equipment in use.

## 2. MILITARY STANDARDS AND SPECIFICATIONS

The reliability, maintainability, and testing of military electronic equipment is specified by military standards (MIL-STD) and specifications (Mil-Specs), which give detailed coverage of component design, construction, and testing.

The military approach emphasizes equipment capability to perform a mission rather than cost of acquiring an equipment. In addition, its procurement practices must comply with numerous regulations. The advanced technology of the equipment makes it necessary for the buyer to accept some of the commercial risk of development. Another major element of the military approach to reliability and maintainability is that if the equipment will be used in combat, the equipment supplier is not likely to be a participant in field improvement.

The MIL-Spec/MIL-STD approach to electronic equipment procurement can be illustrated by the U.S. Navy's specification process, which is based on the General Specification. This is generally applicable to all Navy ships and is supplemented for each ship design by a Detail Specification, which expands on the General Specification, emphasizing applicable sections and deleting those which are not pertinent.

The General Specifications have 157 sections, including general administrative, design, and construction requirements, and detailed requirements on machinery, electrical, and electronic design. General Specifications also cover weapon systems and aviation items, which are, respectively, under the cognizance of the Naval Ships Systems Command and NAVAIR.

Electronic systems are described in 12 sections. Section 400, "General Requirements of Electronic Systems", sets forth standards for design and installation. It cites the Institute of Electrical and Electronic Engineers (IEEE) Standard No. 45, "Recommended Practice for Electric Installations on Shipboard", for guidance on installation practices. This standard is frequently used for nonmilitary shipboard electrical installations. The Navy's General Specifications are more detailed than the corresponding nonmilitary documents, and even they represent only a small percentage of the procurement requirements. The great bulk of the procurement requirements for military electronic hardware are found in the military specifications. MIL-S-24259, the general specification for all Naval electronic equipment, establishes the basic design requirements for Naval shipboard interior communications equipment. MIL-S-24250 is a general specification for shipboard electronic, interior communications, and navigation equipment.

3. THE "TYPE APPROVAL" PROCESS UTILIZED BY SEVERAL FOREIGN CERTIFICATION SOCIETIES, THE ABS, THE USCG, AND THE USN FOR SELECTED EQUIPMENTS

A type-approval process is a procedure by which a prototype unit is tested to ensure that equipment performance under conditions of stress is as claimed by the manufacturer. The type-approval approach differs from the MIL-STD/Mil-Spec and CAAM approaches in that the manufacturer is not responding to a particular requirement of a user. The user has the freedom to set his own requirements and uses a list of off-the-shelf type-approved equipment to evaluate the ability of the equipment to meet his requirement. The contract for the supply of this equipment results from individual negotiations between the buyer and the seller.

To receive type approval, production equipments must perform in accordance with the manufacturer's claims during tests that accurately reflect severe shipboard operational conditions. Several foreign ship certification societies, as well as the ABS, the U.S. Coast Guard, and the U.S. Navy, give some type of approval on a variety of equipment types. Each approval agency specifies test conditions, supervises testing, and enforces compliance with current rules and practices. Each approving agency quantifies what is meant by severe conditions. Once approved, the equipment can be installed aboard any ship classed by the certification society.

The type-approval process can take a variety of forms. Tests may be conducted at the manufacturer's plant, at the buyer's premises, at an independent testing facility, or aboard ship following installation. Inspection of installation quality may also be required. Test requirements can vary, however. An approving agency may not actually control tests at all, but only approve the manufacturer's test facilities and conditions. Approval of automatic engine-room equipment and communications and navigation equipments by means of electronic and instrumentation testing procedures has been specified by only a few societies. Type approval has been more universally required of hull equipments, safety equipments, and piping systems, among others.

Equipment submittal is voluntary, but many foreign societies state that the use of only approved equipments is a condition of ship certification. In practice, only ships certified by the ABS or foreign societies can obtain insurance from marine underwriters.

The approving agency may require the submittal of drawings, technical manuals, parts lists with environmental limitations, circuit diagrams, and detailed operational descriptions.



## APPENDIX B

### SUMMARY OF WORK PERFORMED AND CONCLUSIONS AND RECOMMENDATIONS OFFERED DURING PHASE I OF THE R&M IMPROVEMENT PROGRAM (APRIL 1976 - APRIL 1977)

During Phase I, MarAd surveyed the status of R&M technology in use in the U.S. merchant fleet and examined the R&M practices and procedures utilized by selected European certification societies for shipboard electronic equipment. The following paragraphs describe the results of the MarAd investigation.

#### 1. STATUS OF RELIABILITY AND MAINTAINABILITY TECHNOLOGY IN USE IN THE U.S. MERCHANT FLEET

The objective of the work undertaken by MarAd was essentially to determine the status of reliability/maintainability technology in use in the U.S. merchant marine community in general and, more particularly, as it is applied to shipboard equipment. In addition, the acquisition process for shipboard equipment was studied and the interrelationship of marine organizations related to the reliability/maintainability of marine equipment was identified. During the course of the work performed, prior research work was reviewed to determine its applicability to the MarAd R&M Improvement Program.

In the marine industry, "reliability" means different things to different people. To the ship operator, for example, reliability is related to whether the equipment is available when he needs it. To the U.S. Coast Guard, reliability is related to "safety". During the Phase I investigations, it became evident that reliability of shipboard equipment was determined on the basis of a general opinion about a particular class of equipment rather than from accurate data on equipment failure history. However, it was noted that knowledgeable individuals within the industry considered electronic equipment failure more prevalent than it "should be". They also believed that the reliability of electronic equipment aboard ship was going to become more important to ship operability than it had been in the past.

Our research indicated that during the process of ship design, little if any formal reliability engineering was applied. During the ship construction process, however, the ship-builder does attempt to introduce reliability considerations

into the specifications for shipboard equipment. The specifications used by the shipbuilder in acquiring shipboard electronic equipment are often written by the electronic equipment vendors themselves, in contrast to the procedure followed for ship machinery. The shipbuilder finds himself constrained to a small number of vendors when he is required by contract to purchase U.S.-made equipment. An example of this situation is provided by the commercial radar equipment market. There are currently only two U.S. manufacturers of commercial radar (10 cm and 3 cm) equipment. This situation creates a seller's market in which the shipbuilder finds it difficult, if not impossible, to insist on stringent performance or reliability requirements.

During the construction process, the shipbuilder will adhere to the construction rules of the American Bureau of Shipping (ABS) in order to receive the ABS certification for the vessel. However, our research indicated that these rules are directed primarily to the structural integrity of the vessel rather than to shipboard electronic systems -- although the ABS Guide for Centralized Control and Automation does address electronic equipment aboard ship when such equipment is used to control the ship's engine room. The ABS rules do not specify any requirements for electronic navigation or communications equipment aboard ship. In contrast, the rules of such foreign certification societies as Det Norske Veritas do specify requirements for electronic navigation equipment, including reliability requirements.

The shipbuilder is liable to the owners for the performance of shipboard equipment until the expiration of the "guarantee period", which is usually six months commencing upon delivery of the vessel. During this period the shipbuilder is required to repair any equipment that fails as a result of faulty workmanship or material.

Once the owner has accepted the vessel and has made final payment to the shipbuilder, he is required to maintain the ship and its equipment in good working order. Shipboard equipment maintenance can be subcontracted by the owner/operator to the original equipment supplier, or the owner/operator can operate his own maintenance and repair system. Our research indicated that in the case of shipboard electronic equipment, a better data base on equipment failure history existed when maintenance was performed by the equipment supplier than when it was performed by the ship owner/operator. In each case, the data on equipment failure were closely held and treated in a quasi-proprietary manner. Further, because electronic equipment maintenance is generally performed in port, the time and circumstances of failure are not usually known as accurately as the details concerning the part(s) that failed.

The Maritime Administration reviewed the applicability of prior research to the R&M improvement program being sponsored by MarAd. There is, in the opinion of MarAd, a considerable amount of prior research that is applicable to the current program. The research that was found to be applicable was conducted during the period 1971 to 1975 and was sponsored by the Maritime Administration, the U.S. Navy, and the Society of Naval Architects and Marine Engineers. The essential conclusions reached in prior research work indicate that a comprehensive program is needed within the U.S. merchant shipping industry to improve the reliability of U.S. ships and equipment, that a data base on equipment R&M should be established, that the environmental requirements for shipboard equipment operation must be more precisely defined, and that standard industry specifications for electronic equipment should be developed.

In conclusion, MarAd found that a comprehensive R&M program for shipboard equipment in the U.S. merchant fleet should be established. An essential element of the R&M program should be the operation, on an industry-wide basis, of an information system related to marine-equipment failure. Procedures should also be developed within the industry to establish an ongoing specification development and product improvement program. In this respect, the research into the current state of R&M technology in use in the U.S. merchant shipping industry indicates that MarAd's present work in developing a reliability improvement plan for the U.S. merchant fleet is consistent with the needs of the industry.

## 2. RELIABILITY AND MAINTAINABILITY PRACTICES AND PROCEDURES UTILIZED BY SELECTED EUROPEAN CERTIFICATION SOCIETIES FOR SHIPBOARD ELECTRONIC EQUIPMENT

During Phase I, MarAd conducted a survey of the practices and procedures of selected European ship certification societies in the specification, certification, and approval of marine electronic equipment. Of particular interest was the manner in which the societies imposed reliability and maintainability requirements on the acquisition process for the subject equipment. The certification bodies participating in the survey were:

- Germanischer Lloyd - Germany
- Det Norske Veritas - Norway
- Registro Italiano Navale - Italy
- Bureau Veritas - France
- Lloyds Register of Shipping - United Kingdom



In addition, since the United Kingdom Department of Trade publishes specifications for certain shipboard equipment, the practices and experiences of that organization were also included.

This survey revealed that, with the exception of Det Norske Veritas, little formal reliability engineering is applied by the certification societies relative to the acquisition of shipboard electronic equipment. All societies interviewed address equipment reliability indirectly, but Det Norske Veritas is the only one having an in-house reliability engineering capability. In addition, although all societies certify engine room automation systems, only Det Norske Veritas certifies bridge and navigation systems.

Data collection systems are operated by Lloyds Register of Shipping, Det Norske Veritas, and Germanischer Lloyd. The Lloyds Register system acquires data when a Lloyds surveyor is called to inspect a vessel after structural or equipment failure. Also, in certain cases where the ship owner finds it beneficial, detailed failure data are collected on a particular system for a fixed period and the data are analyzed jointly by Lloyds and the owner. Typical purposes are to determine the reliability and maintainability of the systems, as well as the changes that might be necessary to improve the reliability of the same or similar systems planned for installation in the future.

Germanischer Lloyd operates a manual data collection and analysis system wherein the engineer aboard an automated vessel records failure events as they occur. Circumstances of the failure are described, and the failed item is identified. The failure reports are then forwarded to Germanischer Lloyd, where a review of failures by system is performed. Those systems with a high failure rate are investigated to determine if there is a system or component defect; if there is, the system/component manufacturer is requested by Germanischer Lloyd to rectify the difficulty. Even though the data collection system requires the voluntary cooperation of the ship engineers responsible for recording failure events, the system has proved effective because of the excellent response of shipboard personnel.

Det Norske Veritas (DNV) operates a reliability data collection system in which failure event data are encoded and entered into a computer for subsequent analysis. The system has been adapted from a reliability data base and analysis procedure developed by the Atomic Energy Authority of the United Kingdom, which offers that technical base as a service to industry.

DNV has modified the programs to operate on its computer facilities. The software has an extensive analysis capability and can produce relevant reliability statistics by component, system, or vessel. The system is now successfully operating on a trial basis. DNV intends to investigate the feasibility of using the data collection system within a flexible survey procedure. If a ship operator provides DNV with failure data during the ship's operating cycle, DNV will in turn survey the vessel for certification purposes on a flexible schedule rather than at fixed intervals as at present. The point at which a survey may be required will be determined by an analysis of the failure data. In the opinion of MarAd, it is likely that the failure data collection system will be integrated with a condition-monitoring system. Surveys and maintenance actions will then be established on the basis of equipment condition and change of condition, as well as failure data.

It became evident during the survey that the equipment specification process used by each certification society is unique to that society. It also became apparent that the various societies are in competition with each other. As a rule, the procedures used in equipment certification were influenced by national maritime laws and customs. In the United Kingdom, for instance, the Department of Trade has the authority to publish detailed performance specifications for certain shipboard electronic equipments. The governments in the other jurisdictions, however (as in the United States), rely upon the ship certification society. For example, Det Norske Veritas was the only society visited which certifies bridge and navigation equipment. The Hydrographic Institute of the Federal Republic of Germany issues type approvals for radar equipment, gyrocompasses, echo sounders, and navigation lights. The German Post and Telegraph Department issues licenses for radio transmission equipment. Before a license is issued, a type-approval certificate must be produced.

The purpose of the foregoing observations is to illustrate that the procedure by which shipboard equipment finally arrives aboard a ship varies from country to country, and there is no international standard specification or type-approval procedure for shipboard equipment. In the opinion of MarAd, this situation tends to divide the market for marine equipment into national markets. This complicates the manufacturing and marketing process of the equipment suppliers, reduces the market size, and contributes to higher equipment costs.

Practices and procedures of European certification societies considered potentially applicable to the U.S. merchant shipping industry are:

- A flexible survey system for certified ships, with the time of survey based on an analysis of equipment condition and equipment failure/repair data rather than being a fixed interval
- A manual system of failure/repair data collection and analysis, as operated by Germanischer Lloyd
- A computer-assisted failure/repair data collection and analysis system, as now being tested at Det Norske Veritas



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